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Two times the square of the smallest positive root of $C^{2\nu}_{2n}(x)$ *is smaller than the smallest positive root of* $C^{\nu}_{n}(x)$ *increased by* 1.

Two times the square of the smallest positive root of $C^{2\nu-1}_{2n+1}(x)$ *is smaller than the smallest positive root of* $C^{\nu}_{n}(x)$ *increased by* 1.

The two latter theorems furnish us with a less narrow limitation for the smallest positive root of the function $C^{\nu}_{n}(x)$ than the theorem at the conclusion of § 1.

Terrestrial magnetism. — Dr. W. VAN BEMMELEN. "*"Spasms" in the terrestrial magnetic force at Batavia.*" (Communicated by Prof. H. KAMERLINGH ONNES).

(Read September 30th 1899).

Since the great development of Seismology, the instruments, which record photographically the quantities determining the earth's magnetism have also rendered good service as Seismographs in the researches on the propagation of earth-waves in the surface of the earth.

During half a year I had the opportunity of tracing the seismic disturbances in the Magnetograms at Batavia, and this under very favourable circumstances; for, not only was the fear of local disturbance very small, the temperature constant and the damping large, but since June 1st 1898 a new Milne-Seismograph had been working and furnishing accurate information about seismic disturbances. When an earthquake is near, these appear in the curves of the Magnetograms as discontinuities, viz. the needle suddenly starts vibrating and continues doing so for some minutes; when at a greater distance, on the contrary, only a more or less considerable regular broadening of the curves appears. Comparison with the Milne-Seismograms quickly taught me that the seismic disturbances at Batavia seldom are large enough to appear in the Magnetograms, but also conversely, that no trace of a large number of analogous disturbances in the Magnetograms could be detected in the Seismograms.

Hence there is danger of considerable confusion: if for instance an earth-wave has passed at Batavia at 11.10 which has not appeared in the Magnetograms, then very likely a non-seismic disturbance, occurring at 11.5 for instance, will be mistaken for an earth-wave and an error of minutes will be made. Moreover it is necessary to inquire whether a new phenomenon does not mingle with those just mentioned.

I have given the name "*Spasms*" to these little motions. These appear as broadenings of the curves of the Bifilar-Magnetometer, which may be caused by vibrations of the magnetic force with an amplitude of from 3 to 15 g. (g = 0.00001 C. G. S.) during about 1 to 8 minutes. On the scale of the bifilar-magnetogram 1 m.m. represents 4 minutes and 5 g.

On trying to find an answer to the question, whether there is really evidence of a new kind of small disturbances, I employed two methods, that of statistics and that of direct observation. After the example of ESCHENHAGEN I constructed a Microvariometer for the Horizontal Intensity, in which a light magnet is held perpendicular to the magnetic meridian by the torsion of a German-silver wire. The period of a complete vibration was 9 seconds, the damping ratio 2—7, the value of the tenths of divisions, which could be estimated very easily, 0,06 g.

With this instrument I observed continuously during one or two hours for many nights, and often took readings every fifth second, but unfortunately I have not yet been lucky enough to observe an undoubted Spasm. It occurred on only one occasion and was even then not a striking one.

Notwithstanding this adversity I have been able to learn much from these observations.

For instance I happened to be behind the telescope when a series of faint earth-waves, distinctly registered by the Seismograph, passed Batavia, and though wholly unconscious of this, I nevertheless noted three times horizontal and vertical motions of the magnetic needle. Their period was 2,5 seconds, half that of the free vibration of the magnet.

This observation during the occurrence of a Spasm in the Magnetogram indicated that really a kind of miniature disturbance had passed, and not a prolonged motion, caused by an earthquake. On one occasion I noted, while everything else was quiet, a strong impulse three times in one minute, which caused deviations of 20 to 40 g. The Magnetograms did not show the least signs of these, as the damping of the magnet is too rapid and the paper is not sensitive enough to light. Although my direct observations have not until now met with much success, they nevertheless make the existence of very small *magnetic* disturbances appear probable in this case. Here at Batavia only the curves of the Horizontal Intensity show the Spasms, never those of the Declination which rarely exhibit perturbations at our tropical station.

In compiling the statistics we met with three difficulties:

1st. The number of Spasms detected depends upon the breadth and distinctness of the curves, which are very variable during the registering-period 1883—'99.

2nd. During a very unsettled state of the Magnet it was often impossible to distinguish between the various kinds of disturbances.

3rd. The possibility exists, that many earthquakes have not been noticed, though I had made extracts formerly from the statistics of earthquakes published in the "Natuurkundig Tijdschrift voor Nederlandsch Indië".

Only the difficulty mentioned under 1 is unevitable, and indeed its baneful influence has been keenly felt.

I searched the Magnetograms of the continuous series from March 27 1883 till March 27 1899; for the undulations only the years with narrower curves.

ANNUAL NUMBERS.

	Year	No of Spasms	Period	No of Spasms
Sun-spot maximum	(27 III–31 XII) 1883	(37)	27 III 1883-27 III 1884	55
	» 84	43	» 84- » 85	50
	» 85	64	» 85- » 86	58
	» 86	74	» 86- » 87	81
	» 87	63	» 87- » 88	54
	» 88	43	» 88- » 89	36
(1889.6) Sun-spot minimum	» 89	31	» 89- » 90	51
	» 90	57	» 90- » 91	46
	» 91	45	» 91- » 92	44
	» 92	57	» 92- » 93	53
	» 93	83	» 93- » 94	88
(1894.0) Sun spot maximum	» 94	75	» 94- » 95	74
	» 95	103	» 95- » 96	122
	» 96	114	» 96- » 97	106
	» 97	105	» 97- » 98	96
	» 98	89	» 98- » 99	99
	» 99	(30)		1113
		Total 1130		

If we take into account, that especially in the years 1888—91 the curves are very broad and during the years 92—97 almost invariable in breadth, then a concordance with the number of sunspots appears rather dubious.

Annual variation.

It soon appeared that an annual fluctuation existed in the frequency of the disturbances. Hence I have calculated for a closer inquiry the twelve day and not the monthly means. (Five 13 days periods were made, distributed equally throughout the year.)

Period.	No. of Spasms	Δ	Period	No of Spasms	Δ
1 I —12 I	29	— 8	2 VII —13 VII	21	—16
13 » —24 »	36	— 1	14 » —25 »	25	—12
25 » — 5 II	39	2	26 » — 7 VIII	19	—18
6 II —17 »	57	20	8 VIII —19 »	27	—10
18 » — 1 III	73	36	20 » —31 »	32	— 5
2 III —14 »	64	27	1 IX —12 IX	38	— 1
15 » —26 »	51	14	13 » —24 »	35	— 2
27 » — 7 IV	48	11	25 » — 6 X	49	12
8 IV —19 »	41	4	7 X —19 »	63	26
20 » — 1 V	35	— 2	20 » —31 »	47	10
2 V —13 »	29	— 8	1 XI —12 XI	30	— 7
14 » —26 »	30	— 7	13 » —24 »	41	4
27 » — 7 VI	16	—21	25 » — 6 XII	41	4
8 VI —19 »	26	—11	7 XII —18 »	23	—14
20 » — 1 VII	20	—17	19 » —31 »	28	— 9
				Mean 37	

Hence the annual variation of the Spasms is very clear, and with two maxima. In order to determine even more accurately the dates of the maxima etc., I have calculated the daily numbers for the adjacent months and compared them by means of the formula $a + 2b + c$. A principal maximum certainly appears from these on February 22, a second smaller maximum on October 17; a minimum on December 22 (close to Dec. 20, the mean of Oct. 17 and Febr. 22) and a second very uncertain minimum. Here the comparison of the daily numbers for the period May 23—August 7 by means of the formula

$$\frac{a + 2b + 4c + 6d + 4e + 2f + g}{20}$$

left the choice between June 22 and July 12; and as June 21 is midway between Febr. 22 and Oct. 17, we have good reason for choosing June 22.

The harmonic analysis of the numbers for the 12 days periods yields:

$$D = 37.1 + 10.2 \cos (n \times 12^\circ - 24^\circ 15') + 8.3 \cos (n \times 24^\circ - 67^\circ 53')$$

but this formula does not account for the steeply rising maxima, which demand the terms with 3φ and 4φ and so reduce the cosine-formula to a mere result of calculation. I think it therefore more suitable to defer the deduction of formulae until an explanatory and acceptable hypothesis has been found.

DIURNAL VARIATION.

Hour.	No. of Spasms	Δ	Hour.	No. of Spasms	Δ
0— 1 AM	91	45	0— 1 PM	48	2
1— 2	72	26	1— 2	45	— 1
2— 3	59	13	2— 3	46	0
3— 4	35	—11	3— 4	48	2
4— 5	19	—27	4— 5	39	— 7
5— 6	11	—35	5— 6	47	1
6— 7	8	—38	6— 7	25	—21
7— 8	7	—39	7— 8	43	— 3
8— 9	23	—23	8— 9	66	20
9—10	27	—19	9—10	58	12
10—11	46	0	10—11	103	57
11—12	37	— 9	11—12	110	64

Hence mean 46

Principal maximum (110) 11 —12 PM.
" minimum (7) 7 — 8 AM.
Secundary maximum (48) ± 2 PM
" minimum (25) 6 — 7 PM.

The harmonic analysis of the hourly numbers yields:

$$S = 46.5 + 24.6 \cos (n.\ 15^\circ - 324^\circ 52') + 7.8 \cos (n.\ 30^\circ - 312^\circ 33') + 13.6 \cos (n.\ 45^\circ - 8^\circ 48') + 21.3 \cos (n.\ 60^\circ - 331^\circ 9')$$

Again the term with 4φ is very large. One receives the impression that in the daytime the height of the sun exerts a certain influence for, the minima appear about sunrise and sunset and the maxima, as frequently happens, about midday.

The mean diurnal variation calculated from four maximum and from four minimum months does not show any sensible difference.

DIURNAL VARIATION FOR MAXIMUM AND MINIMUM PERIODS.

H.	Febr.-March Sept.-Oct.	May-June July-Dec.	The Nos. for minimum periods multiplied by 2.
0— 1 AM	44	17	34
1— 2	37	18	36
2— 3	35	10	20
3— 4	12	13	26
4— 5	8	5	10
5— 6	6	2	4
6— 7	3 min.	4 min.	8
7— 8	3	2	4
8— 9	11	4	8
9—10	10	7	14
10—11	18	11	22
11—12	14	10	20
0— 1 PM	24 } max	12 } max.	24
1— 2	21 } max	11 } max.	22
2— 3	12 } max	12 } max.	24
3— 4	21 } max	6	12
4— 5	17	9	18
5— 6	20	12	24
6— 7	12 min.	8	16
7— 8	22	6	12
8— 9	34	18	36
9—10	31	9	18
10—11	42	21 max.	42
11—12	46	21	42
	503	248	496

I further investigated whether any connection existed between the frequency of the Spasms and the tropical and the synodical revolution of the moon, respectively 29,5306 and 27,3216 days; and moreover with the sun's rotation, for the periods: 25,787; 25,800; 25,815; 25,857; 25,929 and 26,071 days.

In none of these cases however was a marked periodicity found, at all events nothing pointing to a direct influence of these revolutions. Such an influence would have been useful for the explanation of the phenomena, we are now considering.

It is not possible now to give an explanation; for that purpose we require, that

1st. The Microvariometer should furnish new material for research;

2nd. The phenomenon is also investigated at other magnetic observatories;

3rd. A theory of the variation of the earth's magnetic force, of the Aurora borealis and of the electric currents in the earth and the high atmosphere has been established.

I will only point out some analogies, which may perhaps contribute afterwards to an explanation.

The deviations, calculated according to VAN DER STOK's method of reduction, can serve as an indication of the amount of disturbance of the Horizontal Intensity at Batavia, especially for the shifting of the lines The table [1]) for the period 1892—93 shows for these deviations

1st. A semi-annual period, with its maxima in March and September, its minima in June and January.

2nd. A diurnal period, with its maximum at 3 P. M. and its minimum at 1 A. M.

3rd. A concordance with the number of sun-spots.

Hence there is agreement between the annual variation of these deviations with that of the Spasms, but not between the diurnal variations.

The photograms giving the Potential of atmospheric electricity show nothing in particular during Spasms, the diurnal variation of the Potential is even reverse and is not semi-diurnal. The annual variation again only contains *one* maximum and *one* minimum. Coincidences in the variations of the meteorological elements are not to be detected. Important coincidences are found with the periodical fluctuations of the Aurora borealis here, in the nightly maximum and the semi-annual periodicity characteristic of this.

The observed numbers have shown, that the epochs of the maxi-

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1) Observations, Batavia, Vol. XVI.

mum and the minimum are altered together with the geographical position, and that the daily variation has no secundary maximum at noon. We should not forget however, how large the influence of moon- and daylight is, and how difficult it is to choose an adequate scale for the Intensity. At lower latitudes the maximum is reached a little before midnight, the minimum about six o'clock in the morning.

The annual variation of the Aurora australis according to BOLLER [1]) is given by:

Jan.	Febr.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
63	104	119	77	44	25	39	52	58	67	63	65

which shows considerable analogy with that of the Spasms; but unlike the Spasms the Aurorae are more numerous during a disturbed magnetic state.

It seems however that a connection exists with a series of wholly different motions in the curves of the Horizontal Intensity, in which for a time varying from a few minutes to several hours the Magnet regularly executes little oscillations with an almost constant period of about 1—4 minutes, and an amplitude of from 1 to 7 g.

I had made these motions already the subject of a careful inquiry, when a remark in the second paper [2]) of Prof. ESCHENHAGEN made it appear probable to me, that Dr. ARENDT had made already a similar investigation for the curves at Potsdam.

Prof. ESCHENHAGEN writes (p. 679): "So far as has been observed until now, these vibrations appear principally in the daytime; at night they are very rare. But frequently at night larger oscillations occur, which are observed even macroscopically in the usual records and which usually occupy whole minutes, though the phenomenon itself seldom lasts for an hour, but usually only for a short time. Already at the beginning of the registering in 1890, attention was paid to this, as the greater distinctness and larger time-scale at Potsdam allowed the phenomenon to be observed there better and more easily than at other observatories. Since then Dr. ARENDT has studied this kind of waves, and he is inclined to the opinion, that they are connected with the phenomena of atmospheric electricity."

This paper of Dr. ARENDT's "Beziehungen der Elektrischen Erscheinungen unserer Atmosphäre zum Erdmagnetismus (das Wetter

[1]) W. BOLLER. Das Sudlicht. Beitrage zur Geophysik. Bd. III. Heft 4. S. 554. 1898.
[2]) Sitzungs Ber. d. Pr Akademie d. Wiss. zu Berlin 1897. June 24.

15*

1896, Heft 11 und 12)", is, I regret to say, not at my disposal here, therefore I will only touch slightly on this matter now.

I have given the name *Pulsations* to these wave motions in the curves, contrasting them thus with the Spasms, because of their resemblance to similar motions in the Seismograms, which were first detected by v. REBEUR-PASCHWITZ and afterwards by MILNE and EHLERT, and to which this name was given by VON REBEUR.

I have compiled statistics of the occurrance of these Pulsations in the years with narrow registering curves, which led to the following result:

1 Jan.—12 July 1885	278 series
1892	267 »
93	169 »
94	97 »
95	241 »
96	230 »
97	249 »
98	197 »

Annual variation for the Period 1892—98.

Jan.	127	July	99
Febr.	116	Aug,	115
March	142	Sept.	101
April	134	Oct.	96
May	144	Nov.	132
June	157	Dec.	87
	820 Series		630 Series

Monthly mean 121.

DIURNAL VARIATION.

Hour.	No. of series of pulsations.	Hour.	No. of series of pulsations.
0— 1 AM	223	0— 1 PM	42
1— 2 »	140	1— 2 »	45
2— 3 »	121	2— 3 »	42
3— 4 »	83	3— 4 »	37
4— 5 »	53	4— 5 »	33
5— 6 »	24	5— 6 »	31
6— 7 »	15	6— 7 »	45
7— 8 »	6	7— 8 »	70
8— 9 »	11	8— 9 »	111
9—10 »	26	9—10 »	127
10—11 »	36	10—11 »	162
11—12 »	46	11—12 »	199

Mean 72

The frequency of the Pulsations was tested in vain like that of the Spasms for a concordance with the tropical or synodical revolution of the Moon.

In the yearly values of the frequency of these Pulsations no parallelism with the numbers for the sun-spots can be found, and in the monthly values a not very distinct yearly undulation appears, which however is quite different from that of the Spasms. But, curiously enough, the daily variations in the frequency agree, without being however quite equal, as appears from the following table of the epochs of the maxima etc.

	Spasms	Pulsations
Principal maximum	11—12 P.M.	0—1 A.M
» minimum	7— 8 A.M.	7—8 A.M.
Secundary maximum	± 2 P.M.	± 1 P.M.
» minimum	6— 7 P.M.	5—6 P.M.

The Electrograms at Batavia show nothing remarkable during the occurrence of Pulsations, which means that no simultaneous changes in the Potential can be observed. As regards the slope of Electric Potential in the lower strata of the atmosphere, I think this will not have any influence on the magnet.

In concluding this preliminary communication I will point out, that a magnetic calm favours the development of the Pulsations, which is connected directly with the quiet of night, as shown by the magnetograms at Batavia. This nightly calm is clearly indicated by the diurnal variation of the above mentioned „deviations", and the epoch of the minimum (1 A.M.) practically coincides with the maximum epoch of the Pulsations. But also the minimum epoch of the deviations (3 P.M.) coincides with the epoch of the secondary maximum, and this makes the connection less clear.

Physics. — Dr. FRITZ HASENOEHRL. "*The dielectric-coefficients of liquid nitrous oxide and oxygen.*" (Communication N°. 52, from the Physical Laboratory at Leyden by Prof. H. KAMERLINGH ONNES).

(Read September 30th 1899).

Measurements of the dielectric-coefficients of liquid gases have been made up to the present only by LINDE [1]) and by DEWAR and

[1]) LINDE, Wied. Ann. 56 p. 546.